



**Distribution of Astomatia Schewiakoff, 1896 and  
Hysteroecinetidae Diesing, 1866 (Ciliophora,  
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## Distribution of Astomatia Schewiakoff, 1896 and Hysterocinetidae Diesing, 1866 (Ciliophora, Oligohymenophora) along the digestive tract of *Alma emini* (Oligochaete, Glossoscolecidae) is correlated with physico-chemical parameters

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### Summary

The paper demonstrates the influence of physico-chemical parameters on the distribution of endocommensal ciliates through the gut of the earthworm *Alma emini*. We measured physico-chemical parameters of the intestinal liquid extracted with the vacuum aspiration technique and concomitantly recorded biological parameter (species abundance). Furthermore, correlation analysis between physico-chemical parameters and biological parameter was performed in different compartments. In the foregut, among the eleven species of Astomatia recorded, correlation was significant between *Metaracoelophrya intermedia*, *Coelophrya roquei* and Water Content (WC =  $46.94 \pm 7.77\%$ ). In the midgut, among the nine species of Hysterocinetidae recorded, a significant correlation was observed between *Metaptychostomum ebebdæ*, *Ptychostomum macrostomum* and Electric Conductivity (EC =  $84.55 \pm 12.94 \mu\text{S}/\text{cm}$ ). In the same compartment, a significant correlation was also observed between *Ptychostomum macrostomum* and Total Dissolved Substance (TDS =  $16.20 \pm 3.46\%$ ). In the hindgut, eight species of Astomatia were found, among which significant correlation was obtained between *Coelophrya roquei* and Hydrogen potential (pH =  $7.35 \pm 0.16$ ). In the same compartment, taking into account the eleven species of Hysterocinetidae recorded, a significant correlation was also obtained between *Ptychostomum macrostomum* and pH; *Ptychostomum commune* and WC ( $28.84 \pm 3.97\%$ ). These results suggest that each part of the digestive tract of *A. emini* can be

considered as a set of natural microhabitats in which certain physico-chemical factors generate ecological niches suitable for one or another group of species.

**Key words:** *Alma emini*, Astomatia, endocommensal ciliates, electric conductivity, intestinal liquid, hydrogen potential, Hysteroecinetidae, total dissolved substance, water content

## Introduction

Oligochaeta represent a major component of the soil macrofauna. They are grouped into three ecological categories: epigeic, anecic and endogeic (Bouché, 1972, 1977). *Alma emini* which measures 51 cm on average and weighs 3.8 g is an anecic species belonging to the family of Glossoscolecidae. This fairly pigmented worm is found in the wet soil, near the less polluted rivers. Like all Oligochaeta, it is a hermaphrodite and creates more or less deep galleries, probably, in response to various constraints such as the content of food and water, the temperature or the degree of oxygenation (Jégou et al., 2000). These galleries increase soil macroporosity and, consequently, contribute to its aeration (Lavelle, 1997) and to water infiltration. They also facilitate root soaking in the soil as well as the movements of invertebrates (Jégou et al., 2002). The role of *A. emini* in the formation, dynamics and fertility of soil has been long known (Darwin, 1881). Besides its role of “the engineer” of the soil, *A. emini* is regarded as a microhabitat as its digestive tract lodges an important microbial fauna (protozoa, bacteria, and viruses). The protozoa are mainly represented by ciliates belonging to Heterotrichida Stein, 1859 (Albaret, 1975; Albaret and Njiné, 1975), Hysteroecinetidae Diesing, 1866 (Njiné and Ngassam, 1993; Ngassam et al., 1993; Ngassam and Grain, 1997, 2000) and Astomatia Schewiakoff, 1896 (de Puytorac, 1968, 1969; de Puytorac and Dragesco, 1969a, 1969b; Ngassam, 1983; Fokam et al., 2008, 2012).

These studies demonstrated that several species of ciliates may be found simultaneously in the same worm, each of them living in a given compartment favorable to its development. Up to now, the reason of this stratification still remains unclear. Very few data were known on the living conditions of these endocommensal ciliates from the digestive tract of their host.

The aim of this study is to assess whether physico-chemical parameters (Hydrogen potential; Electric Conductivity; Total Dissolved Substance and Water Content) may influence the distribution

and abundance of ciliate species along the digestive tract of *Alma emini*.

## Material and methods

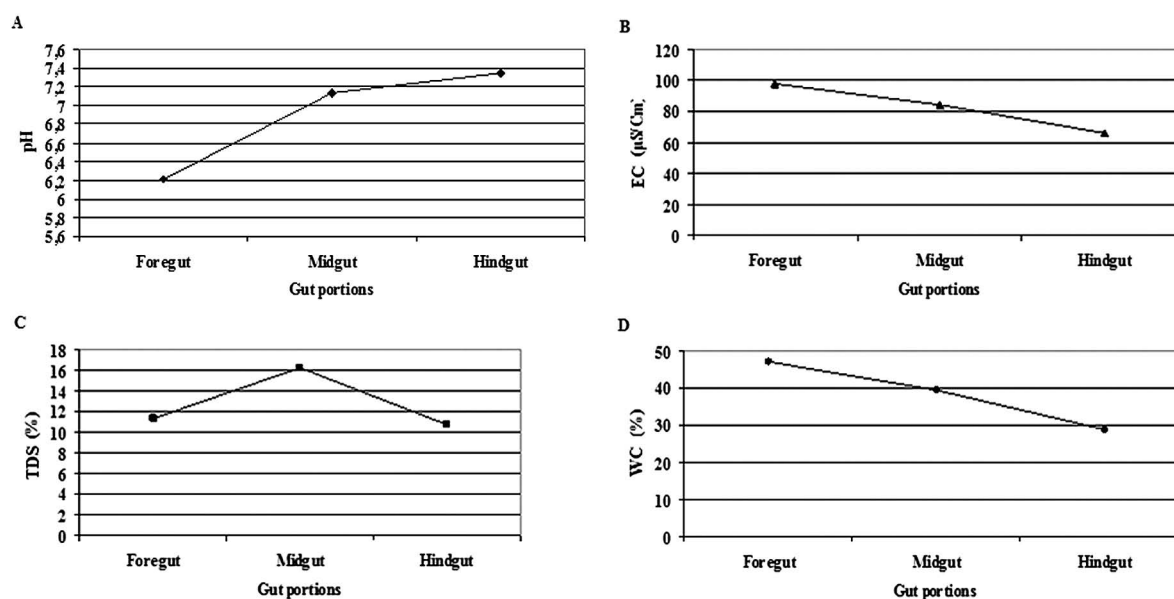
### COLLECTION AND IDENTIFICATION OF EARTHWORMS

Earthworms were collected on Sanaga River bank in Ebebda village, located between 11°30' and 11°50' of Eastern longitude and 4°00' and 4°30' of Northern latitude, 60 km north of Yaoundé-Cameroon (Central Africa) (Fig. 1). Worms were then identified according to the keys described by Sims and Gerard (1999). These worms were randomly divided into two batches for the assessment of physico-chemical parameters and abundance of ciliate species present in their digestive tract.

### MEASUREMENTS OF PHYSICO-CHEMICAL PARAMETERS OF THE EARTHWORM'S INTESTINAL LIQUID

Once in the laboratory, the first batch of earthworms was carefully washed with tap water, and then fixed using formalin (10%). The digestive tract of each of these worms was then separated from the rest of its body and stretched on a filter paper. Once the blood and the coelomic liquid dried up, the intestine of worms was divided into three equivalent portions (fore-, mid- and hindgut) (Fig. 2). The content of each portion of the digestive tract was emptied in an earthenware dish by applying a slight pressure to the walls of the intestine, moving from the middle towards the extremities. The intestinal content was placed on a glass with very fine meshes (1–2 µm). The yellowish liquid was aspirated using a vacuum pump and collected in a flask. This technique, developed by de Puytorac and Mauret (1956), is fast and allows the collection of three to four drops of the intestinal liquid deprived of any particles. In order to collect sufficient amount of the earthworm's digestive liquid for direct measurements of physico-chemical parameters, 15 earthworms were used for each series of experiment. Thirty three series of identical experiments were performed during the whole study.





**Fig. 3.** Variation of physico-chemical parameters along the digestive tract of *Alma emini*. A – Hydrogen potential (pH), B – electric conductivity (EC), C – total contents in dissolved substances (TDS), D – water content (WC).

hindgut (Fig. 3A). Thus, the acid pH in foregut of the digestive tract of earthworms became alkaline in its mid and the hind portions. The average pH of the whole intestinal liquid of the worm was close to neutrality ( $6.90 \pm 0.25$ ).

The mean value of EC in the fore-, mid- and hindgut were  $97.51 \pm 11.18 \mu S/cm$ ,  $84.55 \pm 12.94 \mu S/cm$ , and  $66.22 \pm 8.60 \mu S/cm$  respectively (Fig. 3B). Then, the greatest ionic concentration was obtained in the foregut.

The TDS was on average  $11.38 \pm 2.41\%$  in the foregut,  $16.20 \pm 3.46\%$  in the midgut, and  $10.75 \pm 3.76\%$  in the hindgut (Fig. 3C). Globally, the mean value of this parameters  $12.77 \pm 3.21\%$ .

The WC decreased gradually from the foregut to the hindgut, with average values of  $46.94 \pm 7.77\%$  in the foregut,  $39.27 \pm 5.05\%$  in the midgut, and  $28.84 \pm 3.97\%$  in the hindgut (Fig. 3D).

The Kruskal Wallis 'H' test appeared significant for the whole of the measured parameters ( $P < 0.05$ ) (Table 1). Thus, for each variable, the Mann Whitney 'U' test showed a significant difference among the three portions of the digestive tract of *A. emini* taken

two by two: foregut and midgut ( $P < 0.05$ ), foregut and hindgut ( $P < 0.05$ ), midgut and hindgut ( $P < 0.05$ ) (Table 2).

#### CILIATE BIODIVERSITY

Twenty three species belonging to nine genera of ciliates were found during this study. Twelve species belonged to the Subclass of Astomatia: *Almophrya bivacuolata* de Puytorac and Dragesco, 1969b; *Almophrya mediovacuolata* Ngassam, 1983; *Almophrya laterovacuolata* de Puytorac and Dragesco, 1969b; *Dicoelophrya almae* de Puytorac and Dragesco, 1969b; *Dicoelophrya mediovacuolata* Fokam et al., 2012; *Paracoelophrya intermedia* de Puytorac, 1969; *Paracoelophrya polymorphus* Fokam et al., 2012; *Paracoelophrya ebebdensis* Fokam et al., 2012; *Metaracoelophrya intermedia* de Puytorac and Dragesco, 1969a; *Coelophrya roquei* de Puytorac and Dragesco, 1969b; *Coelophrya ovals* Fokam et al., 2008; *Coelophrya ebebdensis* Fokam et al.,

**Table 2.** Values of the 'U' Mann-Whitney test\*.

Parameters	Foregut	Midgut	Hindgut
pH	0.033	0.037	0.030
EC	0.024	0.020	0.019
TDS	0.027	0.035	0.031
WC	0.021	0.032	0.021

**Table 1.** Overall comparison of the different physico-chemical parameters in the different portions of the digestive tract\*.

Parameters	pH	EC	TDS	WC
P-value	0.010	0.047	0.022	0.034

Notes: \* – correlation is significant at the 0.05 level; EC – electric conductivity; pH – Hydrogen potential; TDS – total dissolved substances; WC – water content.

Notes: \* – correlation is significant at the 0.05 level; EC – electric conductivity; pH – Hydrogen potential; TDS – total dissolved substances; WC – water content.



**Table 3.** Species richness and variation of ciliates abundance along the digestive tract of *A. emini*.

Species		Digestive tract		
		Foregut (m ± sd)	Midgut (m ± sd)	Hindgut (m ± sd)
Astomatia	<i>Almophryra bivacuolata</i>	58 ± 11	25 ± 4	0
	<i>Almophryra mediovacuolata</i>	73 ± 10	28 ± 5	0
	<i>Almophryra laterovacuolata</i>	14 ± 3	7 ± 1	0
	<i>Dicoelophrya almae</i>	0	23 ± 7	5 ± 2
	<i>Dicoelophrya mediovacuolata</i>	0	20 ± 5	7 ± 2
	<i>Paracoelophrya intermedia</i>	48 ± 8	27 ± 5	3 ± 1
	<i>Paracoelophrya polymorphus</i>	33 ± 6	19 ± 4	1 ± 0
	<i>Paracoelophrya ebebdensis</i>	56 ± 7	34 ± 7	18 ± 7
	<i>Metaracoelophrya. intermedia</i>	32 ± 6	18 ± 8	1 ± 0
	<i>Coelophrya roquei</i>	62 ± 4	24 ± 3	1 ± 0
	<i>Coelophrya ovals</i>	27 ± 4	16 ± 3	0
	<i>Coelophrya ebebdensis</i>	59 ± 9	23 ± 6	0
Hysterocinetidae	<i>Metaptychostomum ebebdae</i>	0	17 ± 3	6 ± 2
	<i>Metaptychostomum pirimorphus</i>	0	14 ± 4	7 ± 2
	<i>Ptychostomum sanagae</i>	0	13 ± 4	2 ± 1
	<i>Ptychostomum prolixus</i>	0	2 ± 1	12 ± 4
	<i>Ptychostomum commune</i>	0	3 ± 1	17 ± 5
	<i>Ptychostomum macrostomum</i>	0	10 ± 2	13 ± 3
	<i>Ptychostomum elongatum</i>	0	0	12 ± 3
	<i>Ptychostomum variabilis</i>	0	4 ± 2	20 ± 6
	<i>Proptychostomum commune</i>	0	0	11 ± 3
	<i>Proptychostomum simplex</i>	0	4 ± 2	22 ± 3
	<i>Preptychostomum microstomum</i>	0	19 ± 6	6 ± 3

Notes: m –mean; sd –standard deviation.

2008, while the eleven others were Hysterocinetidae: *Metaptychostomum ebebdae* Ngassam and Grain, 1997; *Metaptychostomum pirimorphus* Ngassam and Grain, 2000; *Ptychostomum sanagae* Ngassam and Grain, 2000; *Ptychostomum prolixus* Njiné and Ngassam, 1993; *Ptychostomum commune* de Puytorac, 1968; *Ptychostomum macrostomum* Njiné and Ngassam, 1993; *Ptychostomum elongatum* Njiné and Ngassam, 1993; *Ptychostomum variabilis* Ngassam and Grain, 2000; *Proptychostomum commune* Ngassam and Grain, 1997; *Proptychostomum simplex* Ngassam and Grain, 1997; *Preptychostomum microstomum* Ngassam et al., 1993.

Among the 762 specimens of Astomatia recorded in the digestive tract of *Alma emini*, 462 were found in their foregut, 264 in their midgut and 36 in their hindgut. The abundance of Astomatia then significantly decreased gradually along the digestive tract of earthworms (Table 3).

The Hysterocinetidae ciliates were mostly found in the hindgut (128 specimen), while they were absent in the foregut and only 86 were found in the midgut.

We noted however, the existence of a buffer medium in the midgut where Hysterocinetidae and Astomatia (*Dicoelophrya almae*, *Dicoelophrya mediovacuolata*) ciliates dwelled together. In addition, we noted an effective cohabitation among species of the same genus (*Almophryra bivacuolata*, *Almophryra mediovacuolata* and *Almophryra laterovacuolata*; *Coelophrya ebebdensis* and *Coelophrya roquei*; *Ptychostomum prolixus* and *Ptychostomum commune*) (Table 3).

#### CORRELATION BETWEEN THE RELATIVE ABUNDANCE OF CILIATES AND THE PHYSICO-CHEMICAL PARAMETERS OF THEIR HOST

Table 4 displays the relationship between the ciliate abundance and physico-chemical parameters of the three portions of the digestive tract of their host.

In the foregut, a positive and significant correlation was found between the abundance of the ciliates *Metaracoelophrya intermedia* ( $r = 0.694$ ;

**Table 4.** Correlation between ciliate abundance and physico-chemical parameters in the different portions of the digestive tract.

Species	Foregut				Midgut				Hindgut			
	pH	EC	TDS	WC	pH	EC	TDS	WC	pH	EC	TDS	WC
Astomatia	Almophrya bivacuolata	0.790	0.790	0.958	0.612	0.064	0.829	0.756	–	–	–	–
	Almophrya mediovacuolata	0.474	0.739	0.863	0.189	0.738	0.309	0.926	–	–	–	–
	Almophrya laterovacuolata	0.947	0.780	0.863	0.852	0.724	0.295	0.829	–	–	–	–
	Dicoelophrya almae	–	–	–	–	0.979	0.612	0.750	0.899	0.590	0.152	0.957
	Dicoelophrya mediovacuolata	–	–	–	–	0.729	0.258	0.252	0.630	0.198	0.290	0.428
	Paracoelophrya intermedia	0.926	0.474	0.527	0.831	0.415	0.728	0.544	0.822	0.977	0.417	0.061
	Paracoelophrya polymorphus	0.728	0.649	0.535	0.127	0.446	0.627	0.147	0.959	0.799	0.503	0.438
	Paracoelophrya ebebdensis	0.915	0.223	0.417	0.979	0.709	0.555	0.631	0.811	0.298	0.873	0.689
	Metaracoelophrya intermedia	0.728	0.738	0.177	0.018*	0.242	0.727	0.480	0.605	0.875	0.290	0.498
	Coelophrya roquei	0.589	0.170	0.830	0.036*	0.904	0.100	0.677	0.024*	0.367	0.460	0.792
	Coelophrya ovaes	0.428	0.893	0.36	0.388	0.841	0.188	0.155	–	–	–	–
	Coelophrya ebebdensis	0.270	0.474	0.601	0.304	0.811	0.277	0.346	0.769	0.223	0.223	0.770
Hysterochinetidae	Metaptychostomum ebebdae	–	–	–	–	0.013*	0.059	0.431	0.850	0.305	0.291	0.333
	Metaptychostomum pirimorphus	–	–	–	–	0.140	0.590	0.323	0.788	0.480	0.099	0.524
	Ptychostomum sanagae	–	–	–	–	0.607	0.531	0.746	0.717	0.100	0.935	0.051
	Ptychostomum prolixus	–	–	–	–	0.733	0.775	0.448	0.141	0.261	0.979	0.082
	Ptychostomum commune	–	–	–	–	0.925	0.185	0.872	0.457	0.853	0.355	0.021*
	Ptychostomum macrostomum	–	–	–	–	0.562	0.012*	0.530	0.007**	0.135	0.727	0.758
	Ptychostomum elongatum	–	–	–	–	–	–	–	0.251	0.322	0.931	0.214
	Ptychostomum variabilis	–	–	–	–	0.422	0.199	0.178	0.883	0.448	0.800	0.572
	Proptychostomum commune	–	–	–	–	–	–	–	0.899	0.748	0.936	0.873
	Proptychostomum simplex	–	–	–	–	0.063	0.060	0.787	0.423	0.821	0.408	0.630
	Preptychostomum microstomum	–	–	–	–	0.722	0.957	0.947	0.547	0.430	0.609	0.779

Notes: \* – correlation is significant at the 0.05 level; \*\* – correlation is significant at the 0.01 level; "–" – no value; EC – electric conductivity; pH – Hydrogen potential; TDS – total dissolved substances; WC – water content.

$P < 0.05$ ), *Coelophrya roquei* ( $r = 0.628$ ;  $P < 0.05$ ) and WC.

In the midgut, a negative and significant correlation was observed between the number of the ciliates *Metaptychostomum ebeidae* ( $r = -0.717$ ;  $P < 0.05$ ), *Ptychostomum macrostomum* ( $r = -0.725$ ;  $P < 0.05$ ) and EC. In the same compartment, a negative and significant correlation was also observed between the abundance of *Ptychostomum macrostomum* and TDS ( $r = -0.619$ ;  $P < 0.05$ ).

In the hindgut, a positive and very significant correlation was found between the values of the pH and *Ptychostomum macrostomum* abundance ( $r = 0.755$ ;  $P < 0.01$ ). A significant and positive correlation was also recorded between the number of *Ptychostomum commune* counted in the hindgut and the WC of the digestive tract of the latter ( $r = 0.682$ ;  $P < 0.05$ ), while the correlation between the abundance of *Coelophrya roquei* and the pH was negative and significant ( $r = -0.669$ ;  $P < 0.05$ ).

## Discussion

The present paper aimed to assess whether the physico-chemical parameters (pH, EC, TDS and WC) of *Alma emini*'s digestive tract may influence the distribution and abundance of ciliate species.

The pH of the digestive tract of *A. emini*, collected in acidic soil of Sanaga River bank (Fokam, 2005), increased from the foregut to the hindgut. These results are in accordance with previous experiments carried out on the oligochaetes *Allolobophora savignyi* and *Lumbricus herculeus* collected in alkaline environment where similar variation of the pH of the digestive tract was observed (Simm, 1913; Krieg, 1923; Puh, 1940; de Puytorac and Mauret, 1956), suggesting that the pH of the habitat of the earthworm might not affect this parameter.

The gradual reduction in the total content of ions (TDS and EC) in the digestive tract of *A. emini* might be due to the action of deionizing bacteria present in the digestive tract. Indeed, some authors reported the presence of a strong and much diversified bacterial community in the digestive tract of oligochaetes (Hyun-Jung et al., 2004; Brito-Vega and Espinosa-Victoria, 2009). The progressive decrease of the values of EC observed is in good accordance with the maximum concentration of ions (chloride, sulfate, calcium, potassium, and sodium) observed in the foregut (Maluf, 1940) and detection of a great number of denitrifying organisms in the digestive tract of *Lumbricus rubellus*, *L. terrestris* and *Aporrectodea caliginosa* (Depkat-Jakob et al., 2010).

Regarding TDS in the three compartments

of the digestive tract of *A. emini*, it seems to be concentrated in the first two parts (fore- and midgut), and to be assimilated in the hindgut, thus explaining its reduction in this latter portion of the intestine as suggested by de Puytorac and Mauret (1956).

We observed a progressive decrease, from the foregut to the hindgut, in WC. Such gradient of fluidity had already been reported by Maluf (1940), and then by de Puytorac and Mauret (1956) in *Lumbricus terrestris* and *Allolobophora savignyi* collected in various fields. This parameter seems to be influenced by the habitat or environment (porosity of the soil), and the physiological status of the worm, as previously reported by Edwards (1998) and Lavelle and Spain (2001).

In the digestive tract of *A. emini*, astomes, in their great majority, proliferated in the acid foregut, rich in mineral elements and in fluid. Besides, we noted that the ciliates inhabiting the anterior part of the digestive tract were very mobile. In contrast, in the posterior portion, populated by Hysteroecinetidae and characterized by alkaline pH and low content of mineral substances and water, ciliates were attached to the intestinal wall by their sucker. Along the same lines, de Puytorac and Mauret (1956) had already shown stratification of *Allolobophora savignyi* related to the physico-chemical variables. These results reveal high affinity between ciliates and physico-chemical variables prevailing in their respective biotope. In general, the ciliate abundance in each portion of the digestive tract of *A. emini* was variable, according to the conditions of the medium.

It is important to notice that the stratification of cells is observed not only in the digestive tract of earthworms. Gohre (1943) reported similar trend in three species of the genus *Gregarina*, parasites of the mealworm (*Tenebrio molitor*). Adam (1951) also showed that two successive ciliate fauna can respectively be found in the coecum and the rectum of the large intestine of horses.

Therefore, it appears that the stratification of ciliate species in the digestive tract of a given host might be largely associated with the physico-chemical parameters of this environment and to a lesser extent with the biotic conditions of the habitat of these hosts.

It is also important to notice that the parameters assessed in our study might not be the only factors affecting the abundance of ciliates. Some authors have not detected enzymes (cellulase and chitinase) in the pharynx, the esophagus, the jabot and the gizzard of many worms, but registered them in the anterior part of the intestine (Tracy, 1951; Laverack, 1963; Urbasek, 1990). If Hysteroecinetidae (*Ptychostomum*



*prolixus*, *Ptychostomum commune*, *Ptychostomum macrostomum*, *Ptychostomum elongatum*, *Ptychostomum variabilis*, *Proptychostomum commune*, *Proptychostomum simplex*) thus seem to be able to spare from such diastases, it is possible that Astomatia (*Almophrya bivacuolata*, *Almophrya mediovacuolata*, *Almophrya laterovacuolata*, *Coelophrya ovaes*) have reversely great need for them. A similar case has been demonstrated in *Diplodinium* and *Entodinium* species of the paunch of ruminants. The first have cellulase and cellobiase which enables them to transform cellulose into glucose whereas the second are deprived of it (Tracy, 1951).

Variation of physico-chemical parameters and ciliate species along the digestive tract of earthworms suggests that passage of soil in digestive tract would influence not only physical and chemical properties of soil, but also its microbial biomass, as was previously suggested by Pedersen and Hendriksen (1993), Fischer et al. (1995, 1997), Houjian et al. (2002) and Depkat-Jakob et al. (2010). The density of soil nematodes, protozoa and coliformes also changes after its transit through the intestine of the epigeic earthworms, providing further evidence in favor of this hypothesis (Monroy et al., 2007). Falling into the line, the passage of soil through the digestive tract of earthworms could stimulate (Brito-Vega and Espinosa-Victoria, 2009) or inhibit (Byzov et al., 2007) the growth of microorganisms and mineralizing bacteria.

## Conclusion

The present study reveals that the digestive tract of oligochaetes in general and that of *A. emini* in particular is a set of biotopes with specific physical and chemical parameters responsible for ecological conditions which can favor the development of a particular ciliated fauna. Contrary to Hysteroecetidae, Astomatia mostly proliferate in the acid foregut, rich in mineral elements and fluid. Despite the quite relevant information provided by our study, other factors influencing the distribution of ciliates in their host still remain to be assessed. The importance of various parameters of the medium differs and depends on the particular organism or a group of organisms (its sensitivity to the particular factor) and the amplitude of variations these factors undergo. In the case of endocommensal ciliates of *A. emini*, each parameter has certainly an essential and primordial action. The greatest concentration of cells of each group (Astomatia and Hysteroecetidae) seems to occur in the fore and hindgut, correspondingly. Nevertheless, specimens

of these two groups can be observed in the midgut, qualified as a buffer medium, where tolerant species occur. Each of these species is probably more sensitive to the quality and quantity of substances present in the medium. It is also necessary to consider predation, rate of oxygen, osmotic pressure, nutrients and ions, specific enzymes, interaction with ciliates, bacteria and viruses in digestive tract of *A. emini* in further research.

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## References

- Adam K.M.G. 1951. The quality and distribution of the ciliate protozoa in the large intestine of the horse. *Parasitology*. 41, 301–311.
- Albaret J.L. 1975. Etude systématique et cytologique sur les ciliés hétérotriches endocommensaux. Mémoire du Muséum National d'Histoire Naturelle, Série A. LXXXIX, 1–89.
- Albaret J.L. and Njiné T. 1975. Description de cinq espèces nouvelles de ciliés hétérotriches des genres *Metanycottherus* Albaret, *Pronycottherus* n. gen. et *Plagiotoma* Dujardin, endocommensaux d'oligochètes du Cameroun. *Protistologica*. 11, 305–311.
- Bouché M.B. 1972. Lombriciens de France: écologie et systématique. INRA Ann. Zool. Ecol. Anim. Publication, France, pp. 1–671.
- Bouché M.B. 1977. Strategies lombriciennes. In: Soil organism as components of ecosystems (Eds: Lohm U. and Persson T.). *Ecological Bulletins*, Stockholm, pp. 122–132.
- Brito-Vega H. and Espinosa-Victoria D. 2009. Bacterial diversity in the digestive tract of earthworms (Oligochaeta). *J. Biol. Sci.* 9, 192–199.
- Byzov B.A., Khomyakov N.V., Kharin S.A. and Kurakov A.V. 2007. Fate of soil bacteria and fungi in the gut of earthworms. *Eur. J. Soil Biol.* 43, 146–156.
- Darwin C.R. 1881. The formation of vegetable mould, through the action of worms, with observations on their habits. John Murray, London.
- Depkat-Jakob P.S., Hilgarth M., Horn M.A. and Drake H.L. 2010. Effect of earthworm feeding guilds on ingested dissimilatory nitrate reducers and denitrifiers in the alimentary canal of the earthworm. *Appl. Environ. Microbiol.* 76, 6205–6214.

- Edwards C.A. 1998. Earthworm ecology. St. Lucie Press, Boca Raton, pp. 207–389.
- Fischer K., Hahn D., Amann R. I., David O. and Zeyer J. 1995. *In situ* analysis of the bacterial community in the gut of the earthworm *Lumbricus terrestris* L. by whole-cell hybridization. Can. J. Microbiol. 41, 666–673.
- Fischer K., Dittmar H., Wolfgang H. and Zeyer J. 1997. Effect of passage through the gut of the earthworm *Lumbricus terrestris* L. on *Bacillus megaterium* studied by whole cell hybridization. Soil Biol. Biochem. 29, 1149–1152.
- Fokam Z. 2005. Biodiversité des ciliés astomes, endocommensaux d'oligochètes terricoles de la région de Yaoundé. Thèse de Doctorat 3e cycle, Université de Yaoundé, Cameroun.
- Fokam Z., Ngassam P., Boutin C. and Zébazé Togouet S.H. 2008. Trois espèces nouvelles de *Coelophrya*, ciliés astomes endocommensaux d'*Alma nilotica* (oligochète terricole) du Cameroun. Bull. Soc. Hist. Nat. Toulouse. 144, 27–33.
- Fokam Z., Ngassam P., Nana P. A., Bricheux G., Bouchard P. and Sime-Ngando T. 2012. Révision de la sous-famille des Metaracoelephryinae de Puytorac, 1972 (Oligohymenophora: Hoplytophryida: Hoplytophryidae), ciliés astomes du tube digestif d'oligochètes terricoles d'Afrique: description de cinq espèces nouvelles. Parasite. 19, 41–56.
- Gohre E. 1943. Untersuchungen über den plasmatischen Feinbau der Gregarinen mit besonderer Berücksichtigung der Sexualitätsverhältnisse. Arch. Protistenkd. 96, 221–295.
- Horn M.A., Schramm A. and Drake H.L. 2003. The earthworm gut: an ideal habitat for ingested N<sub>2</sub>O-producing microorganisms. Appl. Environ. Microbiol. 69, 1662–1669.
- Houjian C., Zarda B., Geoffrey R. M., Schonholzer F. and Dittmar H. 2002. Fate of Protozoa transiting the digestive tract of the earthworm *Lumbricus terrestris* L. Pedobiologia. 46, 161–175.
- Hyun-Jung K., Kwang-Hee S., Chang-Jun C.H. and Hor-Gil H. 2004. Analysis of aerobic and culturable bacterial community structure in earthworm (*Eisenia fetida*) intestine. Agric. Chem. Biotechnol. 47, 137–142.
- Jégou D., Cluzeau D., Hallaire V., Balesdent J. and Trehen P. 2000. Burrowing activity of the earthworms *Lumbricus terrestris* and *Aporrectodea giardi* and consequences on transfers in soil. Eur. J. Soil Biol. 36, 27–34.
- Jégou D., Brunotte J., Rogasik H., Capowicz Y., Diestel H., Schrader S. and Cluzeau D. 2002. Impact of soil compaction on earthworm burrow systems using X-ray computed tomography: preliminary study. Eur. J. Soil Biol. 38, 329–336.
- Krieg H. 1923. Die Ernährung des Regenwurms. Auszug aus der Diss., Bonn.
- Lavelle P. 1997. Faunal activities and soil processes: adaptive strategies that determine ecosystem function. Adv. Ecol. Res. 27, 93–132.
- Lavelle P. and Spain A.V. 2001. Soil ecology. Kluwer Scientific Publications, Amsterdam.
- Laverack M.S. 1963. The physiology of earthworms. In: International series monograph on pure and applied biology (Ed. Kerkut A.G.). Pergamon Press, New York, pp. 18–23.
- Maluf N.S.R. 1940. Osmo and volume regulation in the earthworm with special reference to the alimentary tract. J. Cell. Comp. Physiol. 16, 1–175.
- Monroy F., Aira M. and Dominguez J. 2007. Changes in density of nematodes, protozoa and total coliforms after transit through the gut of four epigeic earthworms (Oligochaeta). Appl. Soil Ecol. 39, 127–132.
- Ngassam P. 1983. Trois espèces nouvelles de ciliés astomes des genres : *Almophrya* de Puytorac et Dragesco, 1968, *Maupasella* Cépède, 1910, *Njinella* nov. genre, endocommensaux d'annélides oligochètes de la région de Yaoundé. Protistologica. 19, 131–135.
- Ngassam P. and Grain J. 1997. Six espèces nouvelles d'Hysteroecinetidae appartenant aux deux genres nouveaux *Metaptychostomum* et *Proptychostomum*, ciliés endocommensaux d'un oligochète terricole du Cameroun. Ann. Sci. Nat. Zool., Paris, 13<sup>ème</sup> série. 18, 41–49.
- Ngassam P. and Grain J. 2000. Contribution to the study of Hysteroecinetidae ciliate of the genus *Ptychostomum*. Description of six new species. Europ. J. Protistol. 36, 285–292.
- Ngassam P., Grain J. and Njiné T. 1993. Contribution à l'étude des ciliés hysteroecinetidés : le genre *Preptychostomum* de Puytorac, 1993. Ann. Sci. Nat. Zool., Paris. 14, 127–135.
- Njiné T. and Ngassam P. 1993. Morphogenèse de bipartition de deux espèces de ciliés Hysteroecinetidae du genre *Ptychostomum* Stein, 1890, endocommensaux d'oligochètes Glossoscolecidae. Europ. J. Protistol. 29, 396–406.
- Pedersen J. C. and Hendriksen N. B. 1993. Effect of passage through the intestinal tract of detritivore earthworms (*Lumbricus* spp) on the number of selected Gram-negative and total bacteria. Biol. Fertil. Soil. 16, 227–232.
- Puh Y.G. 1940. Digestive enzyme actions in the gut of the earthworm. Contr. Biol. Lab. Soc. Sci. China. Zool. 13, 120–121.
- Puytorac P. de. 1968. Structure et ultra structure de quatre nouvelles espèces de ciliés Hysteroecinetidae Diesing. Protistologica. 4, 453–467.

Puytorac P. de. 1969. Nouvelles espèces de ciliés astomes endoparasites d'oligochètes Megascolecidae. Bull. Soc. Hist. Nat. Toulouse. 30, 79–95.

Puytorac P. de and Dragesco J. 1969a. Quatre espèces nouvelles de ciliés Astomes chez les *Alma emini* (Mchlsn) (ver Ciodrilina) du Gabon. Annale Stat. Biologie Besse-en-chandesse. 3, 259–266.

Puytorac P. de and Dragesco J. 1969b. Description de six genres nouveaux de ciliés astomes Hoplitophryidae endoparasites de vers Glossoscolecidae au Gabon. Biologie Gabon. 5, 5–27.

Puytorac P. de and Mauret P. 1956. Détermination de certaines des conditions écologiques propres aux différents Ciliés parasites du tube

digestif d'*Allolobophora savignyi* (oligochètes). Bull. Biologique de la France et de la Belgique. 2, 123–41.

Simm K. 1913. Verdauungsvorgänge bei reifen und knospenden Würmern der Gattung *Chaetogaster*. Bull. Acad. Sci. Gracovie, sér. B. Nat., pp. 1–624.

Sims R.W. and Gerard B.M. 1999. Earthworm. FSC Publ., London.

Tracy M.V. 1951. Cellulase and chitinase of earthworms. Nature. 167, 776–77.

Urbasek F. 1990. Cellulase activity in the gut of some earthworms. Revue d'Ecologie et Biologie du Sol. 27, 21–28.

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